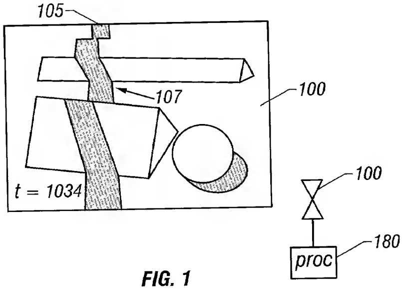

105
107
100
t = 1034
100
180
proc

FIG. 1

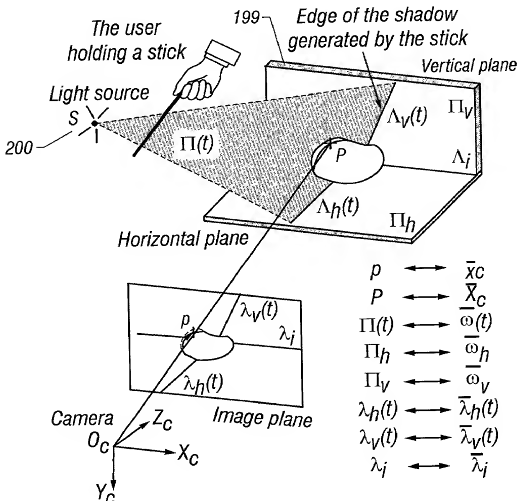

The user holding a stick
199
Edge of the shadow generated by the stick
Vertical plane
Light source
S
200
Π(t)
Λv(t)
Πv
P
Λi
Λh(t)
Πh
Horizontal plane
p
λv(t)
λi
λh(t)
Camera
Oc
Zc
Xc
Yc
Image plane
p ⟷ x̄c
P ⟷ X̄c
Π(t) ⟷ ω̄(t)
Πh ⟷ ω̄h
Πv ⟷ ω̄v
λh(t) ⟷ λ̄h(t)
λv(t) ⟷ λ̄v(t)
λi ⟷ λ̄i

FIG. 2

300 Calibration - find Π_H position

305 Obtain image of the shadow

1)Shadow times at each pixel

2) Locate projections

310 Convert projections (λ) into actual shadow info (Λ)

315 Find shadow plane

320 Find $P \subset X_C$ by triangulation

FIG. 3

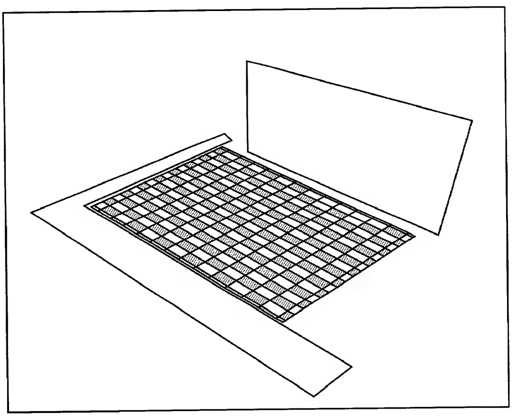


FIG. 4A

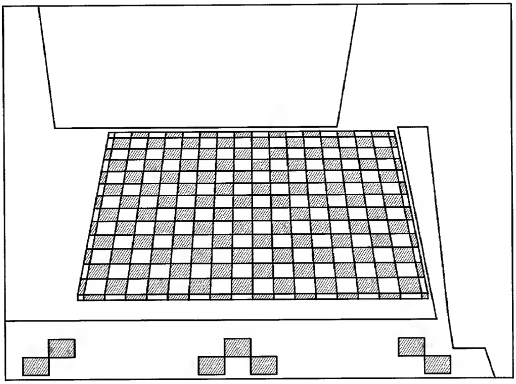


FIG. 4B

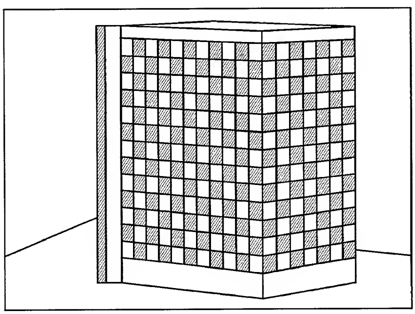


FIG. 5

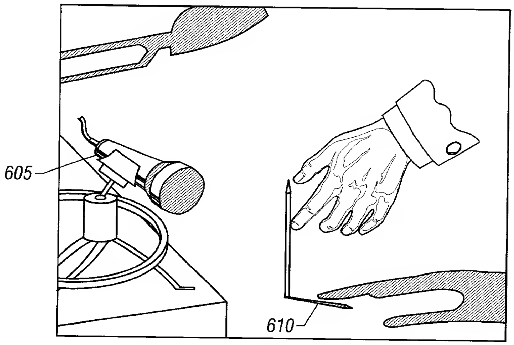


FIG. 6A

A pencil of known height h
orthogonal to the plane

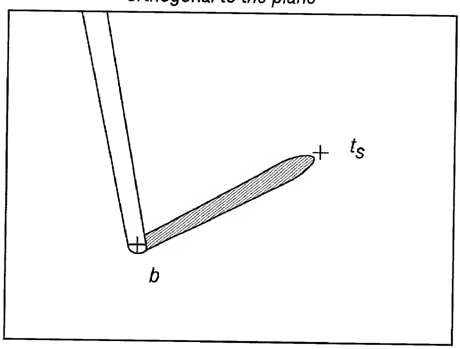


FIG. 6B

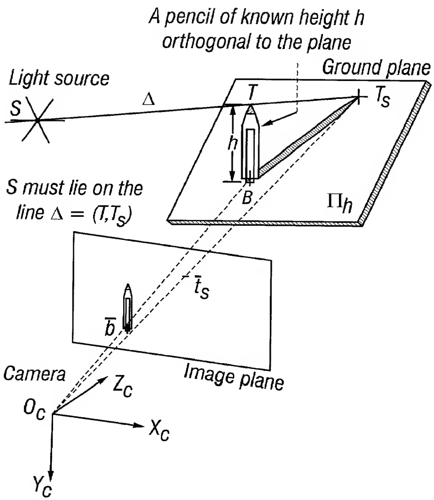

A pencil of known height h
orthogonal to the plane
Ground plane
Light source
S
Δ
T
T_S
h
B
Π_h
S must lie on the
line Δ = (T,T_S)
$\bar{t}_S$
$\bar{b}$
Camera
Z_C
Image plane
O_C
X_C
Y_C

FIG. 6C

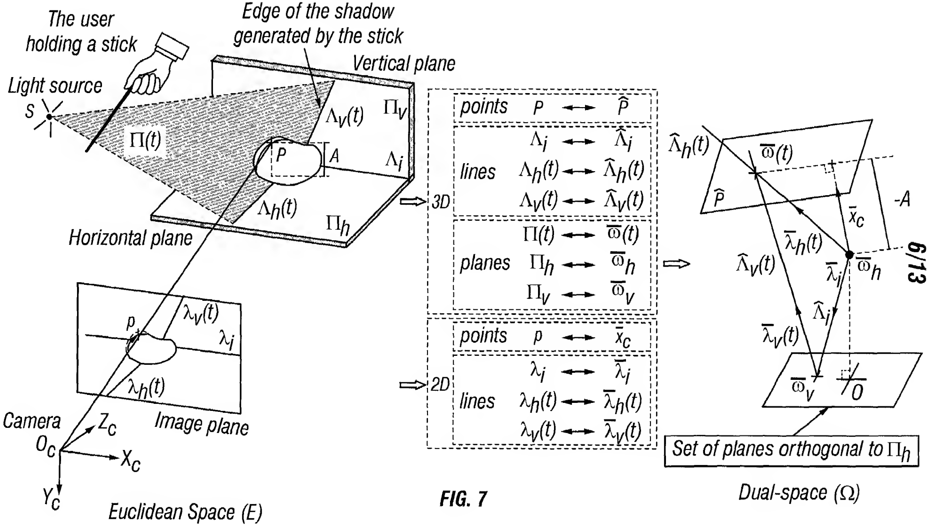
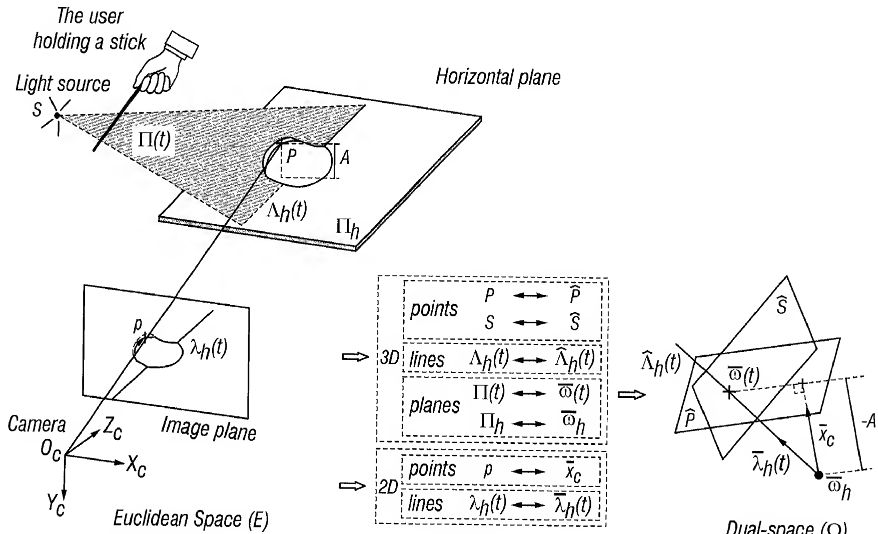

The user holding a stick
Light source
S
Π(t)
Edge of the shadow generated by the stick
Vertical plane
Λv(t)
Πv
P
A
Λi
Λh(t)
Πh
Horizontal plane
p
λv(t)
λi
λh(t)
Image plane
Camera
Oc
Zc
Xc
Yc
Euclidean Space (E)
3D
points P ↔ P̂
lines Λi ↔ Λ̂i
Λh(t) ↔ Λ̂h(t)
Λv(t) ↔ Λ̂v(t)
planes Π(t) ↔ ω̄(t)
Πh ↔ ω̄h
Πv ↔ ω̄v
2D
points p ↔ x̄c
lines λi ↔ λ̄i
λh(t) ↔ λ̄h(t)
λv(t) ↔ λ̄v(t)
Λ̂h(t)
ω̄(t)
P̂
-A
x̄c
λ̄h(t)
Λ̂v(t)
λ̄i
ω̄h
Λ̂i
λ̄v(t)
ω̄v
O
Set of planes orthogonal to Πh
Dual-space (Ω)

FIG. 7



The user holding a stick
Light source
S
Π(t)
P
A
Horizontal plane
Λh(t)
Πh
p
λh(t)
Camera
Oc
Zc
Xc
Yc
Image plane
Euclidean Space (E)
3D
points
P ↔ P̂
S ↔ Ŝ
lines
Λh(t) ↔ Λ̂h(t)
planes
Π(t) ↔ ϖ̄(t)
Πh ↔ ϖ̄h
2D
points
p ↔ x̄c
lines
λh(t) ↔ λ̄h(t)
Ŝ
Λ̂h(t)
ϖ̄(t)
P̂
-A
x̄c
λ̄h(t)
ϖ̄h
Dual-space (Ω)

FIG. 8

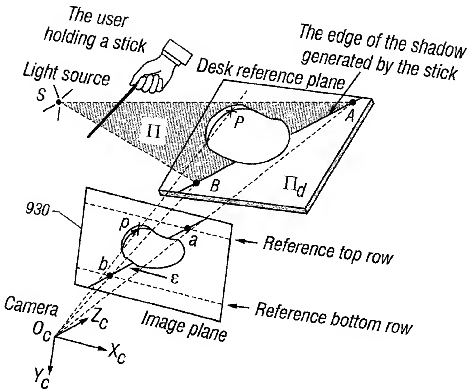

The user
holding a stick
The edge of the shadow
generated by the stick
Desk reference plane
Light source
S
Π
P
A
B
Π_d
930
p
a
Reference top row
b
ε
Camera
O_c
Z_c
Image plane
Reference bottom row
X_c
Y_c

FIG. 9

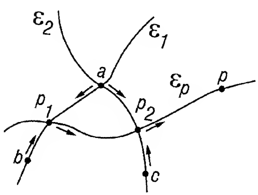

ε_2
ε_1
a
ε_p
p
p_1
p_2
b
c

FIG. 10

successive steps:

Step 1: *Acquire a set shadow images, extract the shadow edges and compute their intersections.*

1120 *Step 2:* *Reject all isolated edges (and isolated groups of edges) so that the entire edge-web is fully connected (def. 2). Results a set of N edges $\mathcal{E}_t$, and N_p intersection points p_t.*

1130 *Step 3:* *Build the 2N x 2N matrix C (eq. 7.10, 7.11 and 7.12), and compute the unitary seed vector $\overline{U}^o$ by SVD. Euclidean reconstruction is then achieved up to the three scalars α, β, and γ.*

1140 *Step 4:* *Select (at least) three points in the scene with known depths, and solve linearly for the remaining scalars α, β, and γ (eq. 7.13).*

Step 5: *Compute the list of shadow plane vectors $\overline{\omega}_i$ (eq.7.7 and 7.2) and triangulate all the points in the edge-web. The resulting set of 3D points may then be triangulated into a surface mesh for visualization purposes (fig. 7.5 and 7.6).*

FIG. 11

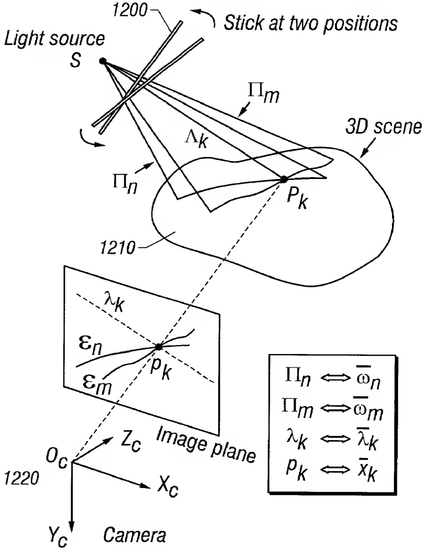

1200
Stick at two positions
Light source
S
Π_m
3D scene
Λ_k
Π_n
P_k
1210
λ_k
ε_n
p_k
ε_m
Z_c
Image plane
O_c
1220
X_c
Y_c
Camera
$\Pi_n \Leftrightarrow \bar{\omega}_n$
$\Pi_m \Leftrightarrow \bar{\omega}_m$
$\lambda_k \Leftrightarrow \bar{\lambda}_k$
$p_k \Leftrightarrow \bar{x}_k$

FIG. 12

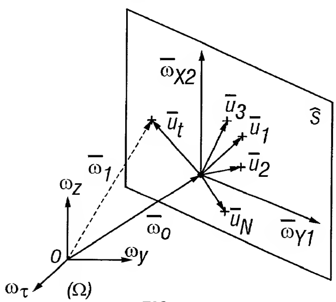

$\bar{\omega}_{X2}$
$\bar{u}_3$
$\hat{s}$
$\bar{u}_t$
$\bar{u}_1$
$\bar{\omega}_1$
$\bar{u}_2$
ω_Z
$\bar{u}_N$
$\bar{\omega}_o$
$\bar{\omega}_{Y1}$
O
ω_y
ω_τ
(Ω)

FIG. 13

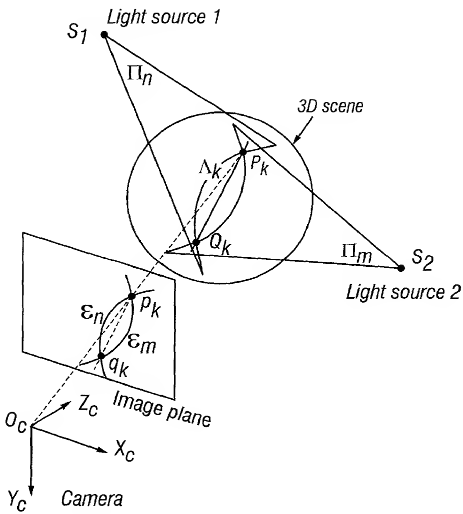

Light source 1
S_1
Π_n
3D scene
Λ_k
P_k
Q_k
Π_m
S_2
Light source 2
ε_n
p_k
ε_m
q_k
Z_c
Image plane
O_c
X_c
Y_c
Camera

FIG. 14

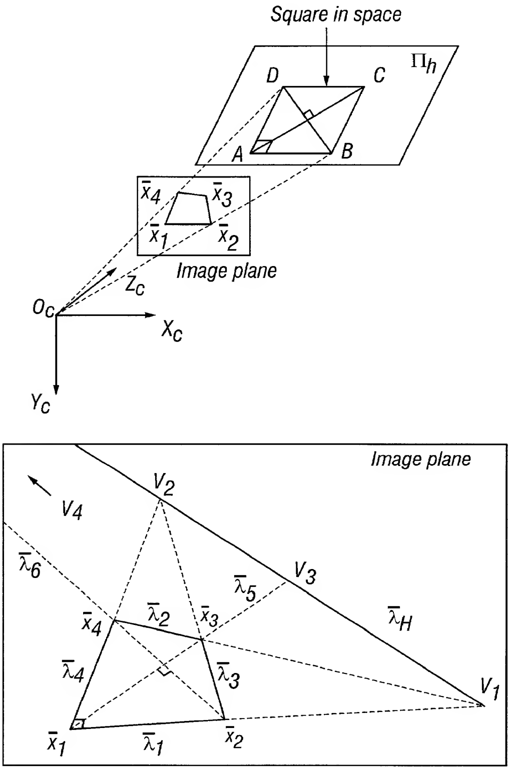

Square in space
Π_h
D
C
A
B
$\bar{x}_4$
$\bar{x}_3$
$\bar{x}_1$
$\bar{x}_2$
Image plane
Z_c
O_c
X_c
Y_c
Image plane
V_2
V_4
$\bar{\lambda}_6$
V_3
$\bar{\lambda}_5$
$\bar{x}_4$
$\bar{\lambda}_2$
$\bar{x}_3$
$\bar{\lambda}_H$
$\bar{\lambda}_4$
$\bar{\lambda}_3$
V_1
$\bar{x}_1$
$\bar{\lambda}_1$
$\bar{x}_2$

FIG. 15

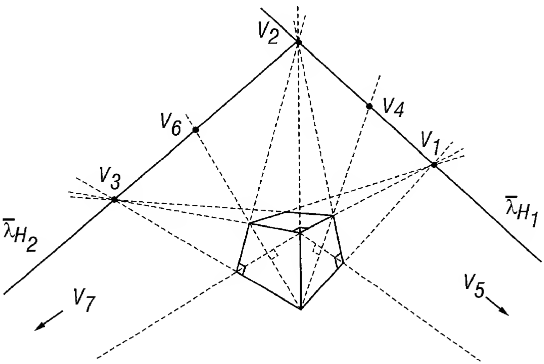


FIG. 16